

A Spatial Hypertext Wiki for Knowledge Management

Carlos Solis and Nour Ali

Lero, the Irish Software Engineering Research Centre

University of Limerick

Limerick, Ireland

{Carlos.Solis,Nour.Ali}@lero.ie

ABSTRACT

Collaboration is a key factor in successful knowledge management. Recently, wikis have become a popular solution for distributed and collaborative knowledge management. However, most wikis do not appropriately support the facilities needed for group idea creation and can only represent unstructured knowledge (text, images, and hyperlinks) which cannot be reused or systematized. This paper proposes the use of a Spatial Hypertext Wiki (ShyWiki) as a knowledge management wiki which allows users to interact in a distributed and collaborative way in order to generate ideas, and organize and structure knowledge. This type of wiki can help in the externalization of tacit knowledge, and is able to represent explicit knowledge at different levels of formality. Furthermore, the visual and spatial characteristics of this wiki can be used for representing implicit relations among concepts as well as for organizing and visualizing knowledge.

KEYWORDS: Knowledge management, spatial hypertext, wiki, ShyWiki.

1. INTRODUCTION

Knowledge Management is composed of the activities, methods, processes, and software that validate, evaluate, integrate, and disseminate information for learning and decision making [26]. A Knowledge Management System (KMS) is an information system that improves the organizational process of creating, storing, retrieving, transferring, and applying knowledge [2].

Wikis have emerged as a popular solution for knowledge management [15, 36, 37]. Wikis are collaborative hypertext systems where users are authors and organizers

of the content [17]. Wikis provide simple editing mechanisms which permit the fast evolution of the content. The content in a wiki page is defined using a mark-up language, which allows users to format the content and create links. The entry level for users using a wiki is low, because they do not have to be technical experts in the edition and design of hypertext [8]. The advantage of using wikis as a tool for knowledge management is that the knowledge management tasks such as capturing, searching, and sharing knowledge can be performed in an open, collaborative and distributed way [12].

One of the most accepted models for knowledge management is the knowledge creation spiral [23] which describes how organizational knowledge is converted into different types of knowledge. The diversity of existing types of knowledge such as tacit, explicit, unstructured and structured force organizations to use several knowledge management approaches in order to deal in an effective way with the conversion between the types of knowledge [2].

Wikis lack support for representing different types of knowledge [14]. Therefore, they do not have an effective support to the knowledge creation spiral. Most wikis are able to represent only explicit unstructured knowledge by means of hypermedia: text, images, video, and hyperlinks. Wikis do not provide support for capturing tacit knowledge. Structured knowledge is currently supported by semantic wikis [27]. These types of wikis do not allow users to represent relations among concepts in a visual and spatial way.

This paper proposes the use of a spatial hypertext wiki (ShyWiki) as a wiki for knowledge management. ShyWiki provides a flexible hypertext model that can represent different types of knowledge. Users are able to capture tacit knowledge, and represent explicit knowledge which can be structured or unstructured. ShyWiki is also able to visually and spatially represent implicit relations among

the concepts in the wiki. The wiki characteristics allow users to build the different types of knowledge in a collaborative way.

This paper is organized as follows: Section 2 explains the knowledge types used in the knowledge spiral. Section 3 explains what spatial hypertext is. Section 4 presents the ShyWiki Hypertext Model. Section 5 explains the knowledge conversions in ShyWiki. Section 6 presents the related work. Finally, section 7 gives the conclusions and the future work.

2. KNOWLEDGE TYPES AND THE KNOWLEDGE SPIRAL

In this work, the taxonomy of knowledge types proposed by Nonaka [23] is followed. Knowledge is classified into two dimensions which are tacit and explicit. Tacit knowledge is composed of intuitions, unarticulated mental models, or technical skills [25, 23]. Tacit knowledge is personal, context specific and hard to communicate to others. Tacit knowledge has individual cognitive elements such as mental maps, beliefs, paradigms and viewpoints, concrete technical elements (know-how), and context specific skills [2].

Explicit knowledge is articulated, codified, and can be communicated in natural or symbolic languages [23]. Explicit knowledge can be processed by computers. Explicit unstructured knowledge does not have a structure which explicitly indicates the correspondences to the concepts and relations in a domain, e.g., plain text and images are unstructured. On the other hand, structured knowledge can be represented using logic or models. The most common way for representing structured knowledge is through a graph where nodes correspond to facts or concepts, and arcs correspond to the relations between concepts, both nodes and links are usually typed [31].

Nonaka also divides knowledge in collective and individual [23]. Individual knowledge is created and exists in an individual. Collective knowledge is created as a result of the actions of a group of individuals.

Organizational knowledge is created by a dynamic process called the knowledge creation spiral [23] (see Figure 1). The spiral has four types of knowledge conversion: socialization, externalization, combination and internalization.

The process can start from any of the four knowledge conversion. In socialization, tacit knowledge of an individual is shared with a group, it is a conversion from individual tacit to collective tacit knowledge. In

externalization, tacit knowledge is transformed into explicit knowledge by capturing ideas and experiences of experts in order to solve particular problems. In combination, explicit unstructured knowledge can be transformed into a different level of systemic explicit knowledge. Internalization is the conversion from explicit to tacit knowledge.

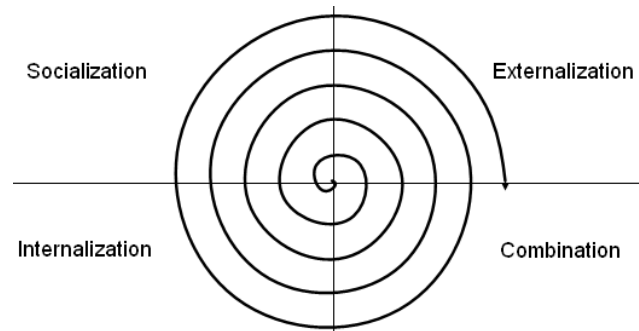


Figure 1. Knowledge Creation Spiral (Adapted from [23])

The knowledge spiral conversions are supported by collaborative systems. Externalization is supported by groupware systems that allow users to brainstorm or create arguments [22]. Externalization is a collaborative interpretation task [7] which is performed by a group when they transform pieces of information into meaningful descriptions. One of the main characteristics of collaborative interpretation is the emergence of ideas. The requirements, defined by Cox and Greenberg [7], for systems that support the emergence of ideas are:

- Provide a spatial visual workspace.
- Let people express relationships between the data using spatial proximity.
- Allow free-form annotation of the underlying space.
- Allow the free creation and movement of data in the space.

A technique commonly used for externalization is the Kawakita Jiro (KJ) method [16] which is used by Japanese companies to brainstorm, evaluate and organize information [22]. The KJ method is a three phases brainstorming session. In the first phase, ideas are generated and written on adhesive cards or post-it notes without any evaluation or critique. In the second phase, ideas are grouped. For example, when an idea on a post-it note describes a better solution than the others, it is put over the other notes in order to prioritize it. If the ideas are related, they can be placed near each other. In this way, spatial location can represent a group of notes, e.g. the notes on the right of a board are the notes that contain

requirements about performance. The goal of the third phase is to create a consensus about the solution to be adopted. In this phase, the groups of ideas are evaluated, i.e., ideas of a group are considered to be the best solution, then the second, and so on.

Combination is a process of improving explicit knowledge by organizing it in more logical ways. For example, documents with unstructured text and images can be organized or classified into more detailed themes or topics using collaborative document editors [22, 28], or can be annotated and mapped to concepts and relations in a domain [34]. The objective is to enable the processing of knowledge. Internalization is supported by means of e-learning and knowledge repositories.

A wiki system in order to support the knowledge management spiral, it must provide ways to facilitate externalization, and must be able to represent explicit knowledge with diverse degrees of formality to support combination.

3. SPATIAL HYPERTEXT

The initial hypertext approaches [9] defined document centred navigation where users navigate through documents using hyperlinks. However, using this type of navigation in large networks make users get lost in the hyperspace [4]. A way to solve this problem is by using map based navigation, which explicitly shows the relations among hypertext documents [32].

Spatial hypertext [20] is based on using visual and spatial characteristics of hypertext elements for defining the relationships among them. When these characteristics are used to relate elements, the hyperlinks become implicit [19]. The relations that are explicit in the map are represented using visual and spatial characteristics. For example, the relations of elements in spatial hypertext can be represented in the following ways: The elements in the document can be positioned to form lists, stacks or only being near each other. Also, elements of the same type can be represented by sharing the same visual and spatial characteristics: colour, borders, font types, adornments, layout, position, proximity, geometric relations, etc. The objects can be contained inside other objects, creating collections.

Spatial hypertext systems have special facilities in their user interface. These facilities have been concluded and observed through practice [20]. For example, users can handle and move elements from one place to another in a hypertext document or change the colour, or size of an element. The spatial hypertext document's elements are

seen as post-it notes or bibliographic cards that are classified through visual clues, or spatial position. When information is organized like this, it allows users to describe complex relations among the elements.

4. SHYWIKI HYPERTEXT MODEL

ShyWiki [29, 30] is a wiki which uses spatial hypertext for representing its content. It is designed to support users in creating, storing, editing, and browsing knowledge structures, understood as interconnected networks of information. ShyWiki manages a network of wiki pages (the nodes of the network). Each page is a hypermedia document that is identified by its name and is made up of an unordered set of named attributes called notes. The main function of notes is to define the attributes that characterize the concept represented by a wiki page.

The content of wiki pages is spatially organized. Notes may be placed in different regions of the page, and can be moved around. Notes can have different sizes or colors. The notes can contain a mix of text, hyperlinks, or images. Composite notes can be created from simpler ones, helping in organizing knowledge hierarchically. Figure 2 shows a ShyWiki page. It is composed of notes that are organized spatially, and that are of different sizes and colours. Also, it can be observed that in Figure 2 there are two composite notes.

The components of the ShyWiki Hypertext Model are summarized in Figure 3. The root of a ShyWiki document is the ShyWikiWeb, which is composed of information and knowledge stored in WikiPages, connected by hyperlinks. The WikiPages are composed of notes. The AbstractNote class includes the properties which are common to other types of notes: ContentNotes, TranscludedNotes, and MapNotes. ContentNotes can contain text, images, video and hyperlinks, and can be composed of other ContentNotes.

Transclusion is the inclusion of notes already defined in other wiki pages by reference, i.e., without duplicating them in the including note. A TranscludedNote is a note whose content is defined by another note. MapNotes are used to draw graphs. A MapNote represents a concept, and it is a node in the graph. The arrows in the graph represent the typed hyperlinks that connect two wiki pages.

A template is a wiki page abstract type, and it is also a wiki page. One of the purposes of templates is the classification of other wiki pages. A wiki page can be an instance of one or many templates. If a wiki page instantiates a template, the notes in the template are created in the wiki page.

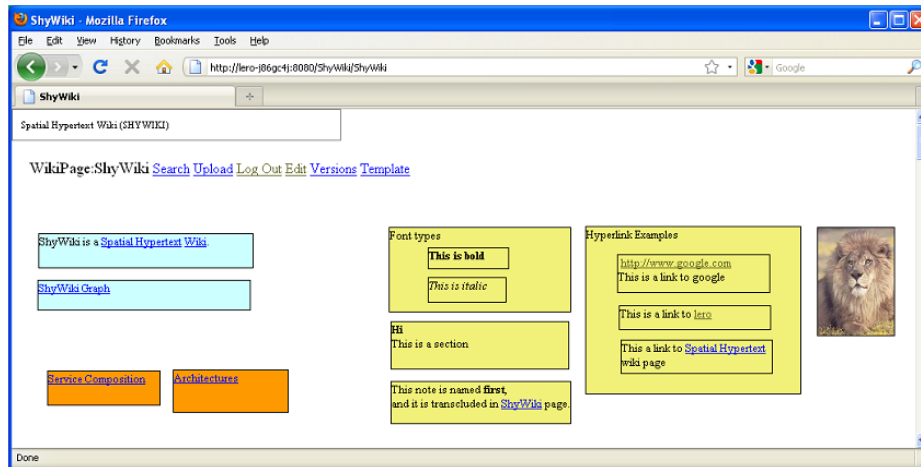


Figure 2. A Wiki Page In ShyWiki

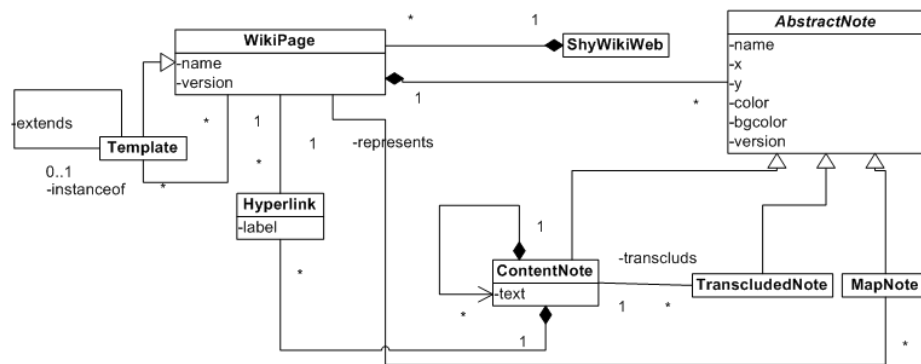


Figure 3. ShyWiki Hypertext Model

In the edit mode, a user can perform the following actions to create or modify wiki pages:

- **Create wiki pages.** When a wiki link is navigated for the first time, a new wiki page in the ShyWiki web is created.
- **Create Notes.** The user can add new notes to the wiki page. The note types that can be added are content, transcluded or map notes.
- **Edit Notes.** The content of notes can be changed anytime. The content of the notes is described using the ShyWiki mark-up language.
- **Move notes.** Notes can be moved freely in the interface by dragging and dropping them. In this way, the user can organize the information as she or he desires.
- **Group notes.** The user can group the notes to create aggregations. In this way, a note can be dragged and dropped inside another note, and the note becomes a part of another one. Once notes

are grouped, a user can manipulate a set of notes together.

- **Transclude notes.** Users can transclude a note inside another wiki page by indicating the source document and the note identifier. The position of the transcluded note can be changed, but the other properties can only be modified if the original note is edited.
- **Label hyperlinks.** Hyperlinks in ShyWiki can be typed. A label indicates the meaning or type of the association represented by a hyperlink.
- **Create a template.** This action allows the user to define a new template. A template defines a set of notes which are inherited by wiki page instances, and associations between a template and others.
- **Instantiate a Template.** This operation is used to indicate that a wiki page is an instance of a template. As a result, the notes defined in a template are added to the current wiki page.

There are three facilities provided by ShyWiki: the versioning facility allows users to look at previous versions of the wiki pages. The search facility that is used to find wiki pages that contain a word or a phrase, and the SPARQL Protocol and RDF Query Language (SPARQL) search interface.

5. KNOWLEDGE CONVERSION IN SHYWIKI

This section explains how ShyWiki supports the externalization and combination knowledge conversions described by the knowledge spiral. ShyWiki features allow users to asynchronously collaborate in the creation of different knowledge types. Distributed Partners working in a global environment need such support.

5.1. Externalization

ShyWiki supports converting tacit knowledge of the individuals into explicit knowledge in a collaborative way. It is a type of idea processing system due to the fact that elements of ShyWiki are similar to adhesive notes. In this way, a brainstorming session is easily supported. In addition, ShyWiki has many advantages over traditional brainstorming systems without losing their simplicity. In ShyWiki, there is no need for using a room with a blackboard or to use paper based notes. A ShyWiki page is a workspace where individuals can write notes. The workspace participants can be geographically distributed providing distributed team work support and write their notes asynchronously. ShyWiki can support different brainstorming sessions in parallel, one for each team working on a particular problem.

The three phases of the KJ method can be developed inside a ShyWiki. The participants can easily enrich other notes: by adding new content to the original ones, or by adding annotations to them. The drag and drop facilities aid in grouping ideas by using relations of proximity (spatial properties) between notes, or covering one note with another to make stacks. The grouping of ideas can also be done by creating big container notes. In addition, the ideas can be classified using background or border colours. As a result, the relations that can be expressed among ShyWiki notes are richer and easier to manipulate than the blackboard or paper based techniques. Figure 4 shows an example of a brainstorming session about security requirements of a web application performed in ShyWiki.

ShyWiki can automatically preserve a brainstorming session, which can be reconstructed if required later on. Furthermore, the use of the versioning facility of a

ShyWiki page can enable a user to track the path followed by a team for making a certain design decision. The decision making process can be reconstructed along with the rationale for the different steps taken during the process.

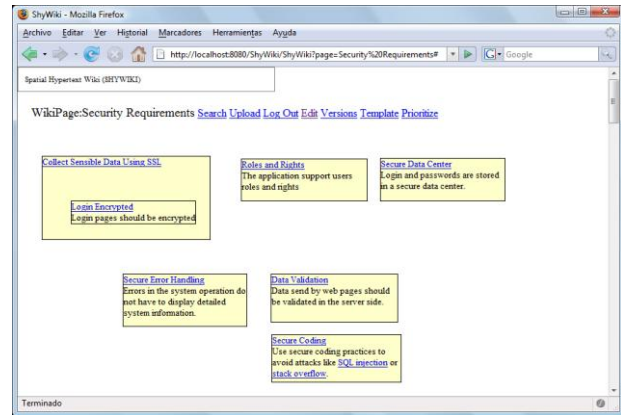


Figure 4. Example Of Brainstorming In ShyWiki

5.2. Combination Using Implicit Relations

Wikis capture explicit unstructured knowledge in the content of their wiki pages as hypermedia. Users are not able to interact with the wiki in order to structure and reorganize knowledge. In ShyWiki, knowledge can be captured in the content of notes. Another type of knowledge captured in ShyWiki, are the relationships among notes that are represented implicitly using visual and spatial properties. They are implicit graphic knowledge structures that can express some logic and set relations [11].

The following logic relations can be expressed graphically: disjoint, intersection, part of, and connection. The disjoint relation (see Figure 5(a)) indicates that two concepts do not have elements in common. The intersection (see Figure 5(b)) indicates that two concepts have elements in common. The part of relation (see Figure 5(c)) points that a concept is part of another. The connection relation (see Figure 5(d)) indicates that two concepts are disjoint, but they are very close to each other.

The set relation is expressed by means of proximity, visual properties, and alignment. A visual colour shared by diverse elements indicates that they belong to the same set or type. For example, assuming that all the grid notes in Figure 6 are in the same wiki page, we can implicitly relate them. A group of elements which are near each other form a set. A group of elements that are aligned form a list. The alignment may indicate an order or priority of the elements. The elements in a set can also

form structures as stacks. Figure 6 shows the different ways of representing a set relation, Figure 6(a) represents a set, Figure 6(b) a list, and Figure 6(c) a stack.

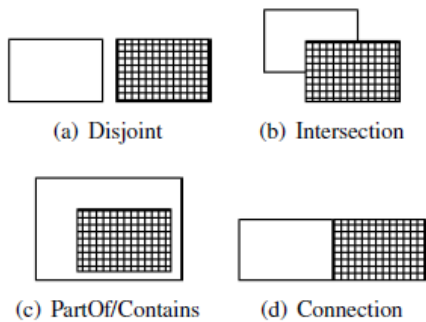


Figure 5. Logic Relations

In ShyWiki, it is possible to represent implicit relations with different cardinalities: one to one (Figure 6(d)), one to n (Figure 6(e)), and m to n (Figure 6(f)). The different ways of expressing graphic relations can be combined to form complex graphic relations.

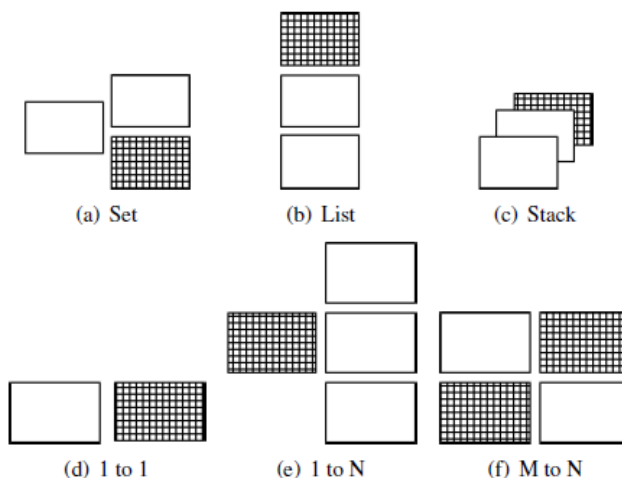


Figure 6. Set And Cardinality Relations

5.3 Combination Using Structured Knowledge

In ShyWiki, structured knowledge is captured by means of named notes, typed hyperlinks, and templates. ShyWiki hypertext can have arbitrary node and hyperlink types, and there is no structural or relational constraint. ShyWiki templates define entity types, their properties and relationships. Typed hyperlinks represent relationships with an explicit meaning between wiki pages. In the following, we explain named notes, typed hyperlinks and templates in detail.

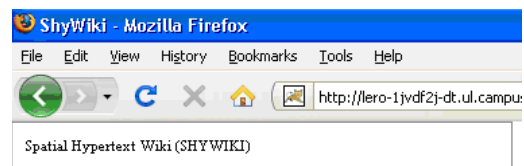
5.3.1. Named Notes

Any note in a wiki page can be optionally named. A named note is a property of the concept represented by a wiki page. A named note is a type of annotation to the content, and serves to describe it. These types of annotations are easier to be used than annotations done in RDF, because these annotations are embedded in the wiki mark-up notation of semantic wikis. A named note can have any type of content. Therefore, it can annotate texts, links, images or a combination of them. The graphic knowledge relations can be used in combination with named notes. In this way, a wiki page can represent relations among notes that represent specific properties of a concept.

5.3.2. Typed Hyperlinks

A typed hyperlink is a relation which has a meaning or type that is indicated by a label. Any hyperlink can be labelled by users. The semantic net representation in ShyWiki is straightforward: the name of a wiki page indicates the concept represented, and the labelled hyperlinks give the semantics to the relations.

In ShyWiki, the syntax for labeling a link is the following: `[[wiki page name | label]]`. The first part indicates the name of the target wiki page of the hyperlink, and the second part is the label of the hyperlink. The interpretation given is that the wiki page where the link appears is related to the target wiki page through a named relation, and the name of the relation is the hyperlink label.



ShyWiki Graph [Edit](#) [Versions](#)

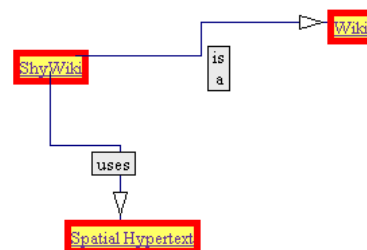


Figure 7. ShyWiki Map

There is a special type of note called MapNote. A MapNote represents a wiki page or concept, and it is used to draw graphs. For example, in Figure 2 there is a note which indicates that ShyWiki is a Spatial Hypertext Wiki. The hyperlink under the word wiki is labelled as 'is a',

and the hyperlink under Spatial Hypertext is labelled as 'uses'. Figure 7 shows another wiki page where three MapNotes were added: ShyWiki, Spatial Hypertext, and Wiki. The ShyWiki tool automatically draws the arrows and labels between the MapNotes.

5.3.3. Templates

A ShyWiki template is an abstraction which represents a set of concepts that share common properties and relationships. A template has an identifier, which is a unique template name. A template defines the properties and relationships shared by its instances. In ShyWiki, properties and relationships are defined by using named notes. A note's name can define the name of a property, and its content is the default value in the instances. The template permits the definition of 1 to 1 and 1 to N relationships. The user has to define a named note, the note's name defines the name of the relation. Then, the associated concept is selected from the template list. The content of the note shows the definition of the relation: a typed hyperlink to a concept instance, which is labeled with the name of the note, followed by an N if the cardinality is 1 to N.

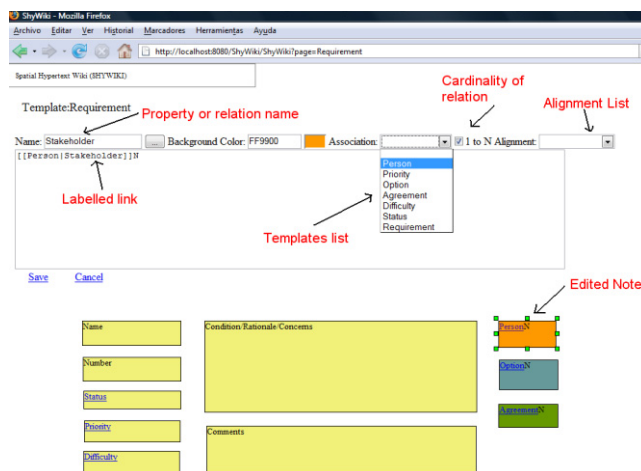


Figure 8. Requirement Template

Figure 8 shows that the user has defined a template called *Requirement*. Each note is defined by giving it a name, a colour and optionally indicating if it represents an association (relationship) of type 1 to N (by default it is a 1 to 1). When a note represents a property, only the name and colour have to be defined. In Figure 8, the notes *Name*, *Number*, *Comments* are properties. Notes *Status*, *Priority*, and *Difficulty* are 1 to 1 relationships. Notes *Person* (stakeholder), *Option*, and *Agreements* are 1 to N relations. Figure 8 also shows that the *Stakeholder* relation is defined. The note's name *Stakeholder* defines the name of the relation, and the associated concept *Person* is selected from the template list. The content of the note

shows the definition of the relation: `[[Person | Stakeholder]]N`.

The instantiation of a template is performed in the following way: when a new wiki page is created, the user has the option to make it an instance of a set of templates. If the user chooses a wiki page to be an instance of a template, the instance includes the properties and relations defined in the template. If the user edits a note which corresponds to a one to one relation, a select box of the instances of the associated template is presented, and the user can select one of these instances. The user can also type a name that is not included in the select box. As a result, the wiki page indicated is declared an instance of the associated template. The definition of 1 to N relationships is similar to the definition of 1 to 1 relationships. When a note corresponding to a 1 to N association is edited then a select box of the possible associated instances and a text box to define a new one are presented. Also, an operation for removing the *instanceof* relation is provided. The result of this operation is the removal of the *instanceof* relation between the template and the instance, but it does not remove any note in the wiki page.

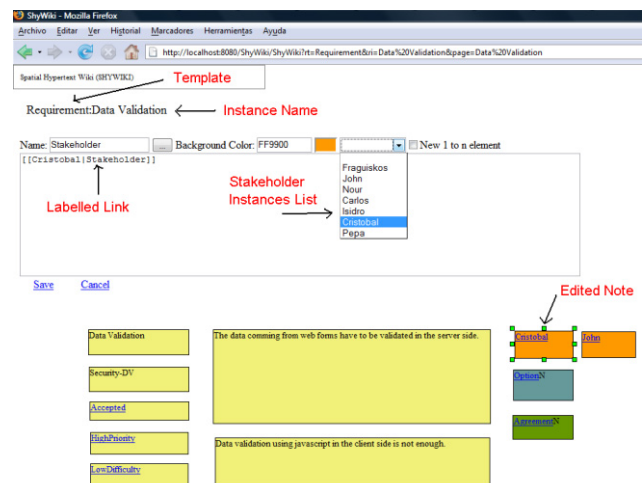


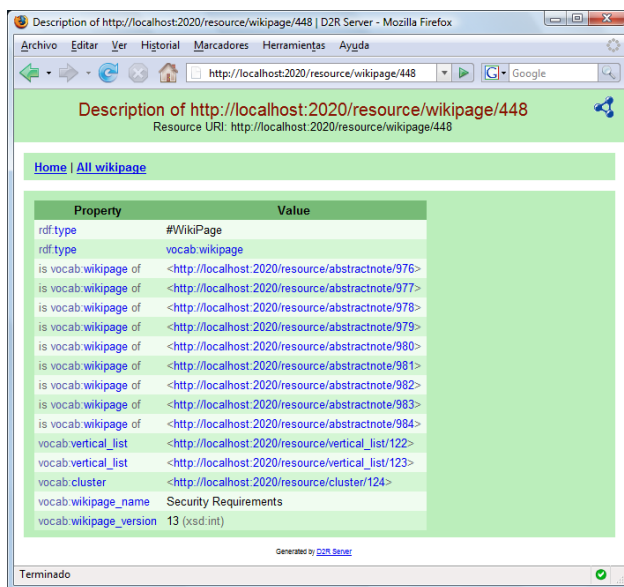
Figure 9. Data Validation Instance Of Requirement

Figure 9 shows the wiki page called *Data Validation* which is an instance of the *Requirement* template. The property name has the value of *data validation*, and the property number has the value of *Security-DV*. The relations 1 to 1 or 1 to N are defined with the help of the note editor that allows the user to choose the associated instances (see drop down menu in Figure 9). The edited note *Cristobal* is a relation to one of the stakeholders of this requirement, as well as *John*.

5.4. Collaboration With Agents

The software agents that need to read the content of ShyWiki can access the RDF wiki page by means of the link relation included in the html: `<link rel='alternate' type='application/rdf+xml' ref='/data/wikibase/30?output=rdfxml' title='This page in RDF'>`.

The RDF projection of the wiki page contains the description of the content of the wiki page. Figure 10 shows the HTML view of the RDF resource of the wiki page *Security Requirements*. It indicates the name of the wiki page (Security Requirements), version (15), and a list of the notes that it contains. Each note is described in another RDF resource. The RDF projections are done using the D2R server [5]. ShyWiki is a service-oriented wiki. ShyWiki web client interacts with the server using Asynchronous JavaScript and XML (AJAX) web services. These services can be used by agents to write or read the content of the wiki.



Property	Value
rdf:type	#WikiPage
rdf:type	vocab:wikibase
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/976>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/977>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/978>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/979>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/980>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/981>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/982>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/983>
is vocab:wikibase of	<http://localhost:2020/resource/abstractnote/984>
vocab:vertical_list	<http://localhost:2020/resource/vertical_list/122>
vocab:vertical_list	<http://localhost:2020/resource/vertical_list/123>
vocab:cluster	<http://localhost:2020/resource/cluster/124>
vocab:wikibase_name	Security Requirements
vocab:wikibase_version	13 (xsd:int)

Figure 10. HTML View Of The RDF Resource Security Requirements

5.5. Example Scenario

A possible scenario where ShyWiki can be used is in the requirements specification of a software system. In this process, many stakeholders (e.g. clients, developers) need to interact in order to come up with the final requirements specification. The stakeholders can be distributed in different places. The first step performed is the elicitation of the requirements, which usually are externalized using brainstorming sessions. In this step, the stakeholders express the initial requirements they want the system to

implement. Later, these initial requirements are classified in groups, and some of them are eliminated if they are duplicated. The last step of the elicitation is the prioritization of the requirements. For example, Figure 4 shows a brainstorming session about security requirements of a web application.

In the next step, the accepted requirements should be specified with more detail. This is the combination of knowledge. For example, accepted requirements can be specified using the *requirement* template of Figure 8. The wiki page will present the different attributes that a *requirement* has. For example, each requirement has a name, description, stakeholders, priority, status, etc. Figure 9 shows an instance of the *requirement* template. In addition, if the software development project is managed using a method such as Scrum, the assignment of tasks related with a requirement (user stories in Scrum) can be managed using the spatial hypertext properties of the wiki pages. For example, a Scrum board can be represented in a wiki page, where note containers represent tasks states, and the colour of a task represents a developer.

6. RELATED WORK

There are several spatial hypertext systems such as: VIKI [21] is one of the first spatial hypertext systems that has focused on the emergent structure of the documents. WARP [10] is a Web-based dynamic spatial hypertext system that is based on applets, and it has an interactive interface. TinderBox [3] is a personal content assistant for visualizing, analyzing, and sharing notes. However, neither of them have wiki behaviour, and they cannot be used for collaboration in the web.

The first WikiWikiWeb was proposed in 1995 [17]. Wikipedia [1] is the biggest collaborative wiki, and it represents the success of the wiki concept. Wikis are a way to provide a usable solution for knowledge management in the organizations [15, 36, 37], in addition, it has been found that wikis in the corporations are sustainable [18]. According to Wagner [35], Wikipedia follows the Bazaar-Style knowledge management, which is characterized by incremental development, multi-person effort, and quality improvement.

Oren et al. [24] propose the use of semantic wikis for knowledge management. Semantic wikis support the combination of explicit knowledge. Semantic wikis permit the application of semantic web knowledge description languages to annotate explicit knowledge and create structured knowledge [27]. Users can create annotations and wiki page types in order to provide richer semantic

descriptions of the content. The first semantic wikis such as Platypus [33] and Semper Wiki [24] allow users to edit the wiki pages and add Resource Description Framework annotations to the wiki pages. Some semantic wikis focus on ontology building such as OntoWiki [13], and SweetWiki [6]. Semantic wikis can represent structured knowledge, but they cannot represent implicit visual and spatial relations among the concepts in the semantic wiki, and neither have good support for externalization. Wen and Jiao developed the Knowledge Fusion Creation Model Wiki [38], which is based on the knowledge management framework of Nonaka, their wiki is another semantic wiki.

In most wikis and semantic wikis the acquisition of knowledge is done using the wiki page editor. Wikis do not satisfy the requirements needed to perform collaborative interpretation. Therefore, they do not have enough support for the externalization of tacit knowledge. ShyWiki gives a more complete support to Nonaka's knowledge creation model than other wikis, because ShyWiki permit the collaborative creation of the different types of knowledge involved in the knowledge creation spiral. In this way, ShyWiki can be considered an improved solution for knowledge management.

7. CONCLUSIONS AND FUTURE WORK

The knowledge spiral for the creation of organizational knowledge involves different types of knowledge conversion. Therefore, managing different types of knowledge is essential in a knowledge management system.

This paper has proposed the use of a spatial hypertext wiki (ShyWiki) for knowledge management. ShyWiki is an implementation of the ShyWiki Hypertext Model. The visual and spatial characteristics make this model suitable for representing three different types of explicit knowledge: unstructured (text, images, and hyperlinks), implicit graphic relations among concept types, and structured knowledge by means of typed concepts and hyperlinks. The visual and spatial characteristics of ShyWiki make it suitable for the externalization of tacit knowledge. ShyWiki fulfills the requirements for systems that support collaborative interpretation, and can be used to perform the KJ method.

ShyWiki is a tool for facilitating the transit from tacit to formal knowledge. Users can incrementally formalize the knowledge in the wiki. They can start with an externalization process, make the knowledge explicit and gradually incorporate annotations, and concept and

hyperlink types. In this way, ShyWiki gives support to the knowledge creation spiral

The on-going work is research about the use of ShyWiki for capturing user requirements and for documenting software architectural knowledge. In the future work, we plan to improve the wiki editor, and perform usability evaluations. In addition, we are working on enriching the ShyWiki tool in order to allow the user to define structured knowledge in a more intuitive way. Our plan is to allow the ShyWiki tool use the implicit spatial and visual properties to infer the structure of knowledge.

ACKNOWLEDGEMENTS

This work was funded by Science Foundation Ireland grant 03/CE2/I303 1 to Lero - the Irish Software Engineering Research Centre (<http://www.lero.ie>).

REFERENCES

- [1] Wikipedia, the free encyclopedia. <http://www.wikipedia.org>. Accessed on February 2010.
- [2] D.E. Leidner, M. Alavi. "Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues." *MIS Quarterly: Management Information Systems*, Vol. 25, No.1, pp. 107–136, 2001.
- [3] M. Bernstein. "Collage, composites, construction." In *Proc. of conference on Hypertext and hypermedia*, 2003.
- [4] M. Bernstein, P.J. Brown, M. Frisse, R. Glushko, P. Zellweger, and G. Landow. "Structure, navigation, and hypertext: the status of the navigation problem." In *Proc. of the ACM conference on Hypertext*, pp. 363–366, 1991.
- [5] C. Bizer. "D2R map - a database to RDF mapping language." In *International WWW Conference*, 2003.
- [6] M. Buffa and F. Gandon. "Sweetwiki: semantic web enabled technologies in wiki." In *Proc. of the international symposium on Wikis*, pp. 69–78, 2006.
- [7] D. Cox and S. Greenberg. "Supporting collaborative interpretation in distributed groupware." In *Proc. of Computer supported cooperative work*, pp. 289–298, 2000.
- [8] W. Cunningham. "Design principles of wiki: how can so little do so much?" In *Proc. of the international symposium on Wikis*, pp. 13–14, 2006.
- [9] D.C. Engelbart. *Authorship provisions in augment* (reprint). pp. 107–126, 1988.

- [10] L. Francisco-Revilla and F.M. Shipman. "Warp: a web-based dynamic spatial hypertext." In Proc. of Hypertext and hypermedia, pp. 235–236, 2004.
- [11] L. Francisco-Revilla and F.M. Shipman. "Parsing and interpreting ambiguous structures in spatial hypermedia." In Proc. of Hypertext and hypermedia, pp. 107–116, 2005.
- [12] H. Hasan and C.C. Pfaff. "The wiki: an environment to revolutionize employees' interaction with corporate knowledge." In Proc. of Australia conference on Computer-Human Interaction, pp. 377–380, 2006.
- [13] M. Hepp, D. Bachlechner, and K. Siorpaes. "Ontowiki: community-driven ontology engineering and ontology usage based on wikis." In Proc. of the international symposium on Wikis, pp. 143–144, 2006.
- [14] S. Huang and C. Yang. "Designing a semantic bliki system to support different types of knowledge and adaptive learning." Comput. Educ., Vol.53, No.3, pp. 701–712, 2009.
- [15] H. Jing and Y. Fan. "Usability of wiki for knowledge management of knowledge-based enterprises." In International Symposium on Knowledge Acquisition and Modeling, pp. 201–205, 2008.
- [16] J. Kawakita. THE ORIGINAL KJ-METHOD. Kawakita Research Institute, 1982.
- [17] B. Leuf and W. Cunningham. THE WIKI WAY: QUICK COLLABORATION ON THE WEB. Addison-Wesley Longman, Boston, USA, 2001.
- [18] A. Majchrzak, C. Wagner, and D. Yates. Corporate wiki users: results of a survey. In Proc. of the international symposium on Wikis, pp. 99–104, 2006.
- [19] C.C. Marshall and F.M. Shipman. "Searching for the missing link: Discovering implicit structure in spatial hypertext." In Hypertext'93 Proceedings, pp. 217–230, 1993.
- [20] C.C. Marshall and F.M. Shipman. "Spatial hypertext: designing for change." Communications of ACM, Vol. 38, No.8, pp. 88–97, 1995.
- [21] C. C. Marshall, F.M. Shipman, and J.H. Coombs. "Viki: spatial hypertext supporting emergent structure." In Proc. of Hypermedia technology, pp.13–23, 1994.
- [22] I. Nonaka, K. Umemoto, and D. Senoo. "From information processing to knowledge creation: A paradigm shift in business management." Technology in Society, Vol. 18, No.2, pp. 203–218, 1996.
- [23] I. Nonaka and H. Takeuchi. THE KNOWLEDGE CREATING COMPANY: HOW JAPANESE COMPANIES CREATE THE DYNAMICS OF INNOVATION. Oxford University Press, USA, May 1995.
- [24] E. Oren, M. Volkel, J.G. Breslin, and S. Decker. "Semantic wikis for personal knowledge management." In Database and Expert Systems Applications, vol. 4080, pp. 509–518, 2006.
- [25] M. Polanyi. THE TACIT DIMENSION. Anchor Books, 1967.
- [26] A. Rhem. UML FOR DEVELOPING KNOWLEDGE MANAGEMENT SYSTEMS. Auerbach Publications, Boston, MA, USA, 2005.
- [27] S. Schaffert, F. Bry, J. Baumeister, and M. Kiesel. "Semantic wikis." IEEE Software, Vol. 25, No.4, pp. 8–11, 2008.
- [28] A. Schmidt. "Knowledge maturing and the continuity of context as a unifying concept for knowledge management and e-learning." In Proceedings of I-KNOW, 2005.
- [29] C. Solis and N. Ali. "Shywiki-A Spatial Hypertext Wiki." In Proc. of the international symposium on Wikis. 2008.
- [30] C. Solis and N. Ali. "Shywiki: A Spatial Hypertext Wiki Prototype (demo)." In Proc. of the international symposium on Wikis. 2008.
- [31] J.F. Sowa. PRINCIPLES OF SEMANTIC NETWORKS. Morgan Kaufmann, 1991.
- [32] H.J. Strauss. "Hypermaps: telling your users where to go." In Proc. of the conference on User services, 1990.
- [33] Roberto Tazzoli, Paolo Castagna, and Stefano Emilio Campanini. "Towards a Semantic WikiWikiWeb". In 3rd International Semantic Web Conference, 2004.
- [34] V.S. Uren, P. Cimiano, J. Iria, S. Handschuh, M. Vargas-Vera, E. Motta, and F. Ciravegna. "Semantic annotation for knowledge management: Requirements and a survey of the state of the art." J. Web Sem., Vol. 4, No.1, pp. 14–28, 2006.
- [35] C. Wagner. "Breaking the Knowledge Acquisition Bottleneck through Conversational Knowledge Management". Information Resources Management, Vol. 1, 2006.
- [36] C. Wagner and N. Bolloju. "Supporting knowledge management in organizations with conversational technologies: Discussion forums, weblogs, and wikis." Database Management, Vol. 16, No.2, pp.1–8, 2005.
- [37] A. Weiss. "The power of collective intelligence." net-Worker, Vol. 9, No. 3, pp. 16–23, 2005.
- [38] Y. Wen and Y. Jiao. "Knowledge fusion creation model and its implementation based on wiki platform." In International Symposium on Information Engineering and Electronic Commerce, pp. 495–499, 2009.